Middle Fossa Surgical Anatomy Related to the Subtemporal Preauricular Infratemporal Approach: An Anatomic Study

Subtemporal Preaurikular İnfratemporal Girişimde Orta Fossa Cerrahi Anatomisi: Anatomik Çalışma

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Abstract: Lesions in the extradural middle and upper clival region, including the posterior cavernous sinus, and those in the infratemporal and middle fossa areas can be accessed by the subtemporal preauricular infratemporal approach. This method requires drilling of the petrous bone and clivus, and mobilization of the petrous internal carotid artery. The anatomy of the petrous apex and middle cranial fossa is complex, and thorough knowledge of the anatomic landmarks in this area is necessary in order to explore the petrous internal carotid artery with minimal risk.

Key Words: Anatomy, clivus, infratemporal fossa, petrous carotid artery, trigeminal nerve

Özet: Subtemporal preaurikular infratemporal girişim orta, üst klival bölge arka kavernoz sinus, infratemporal ve orta fossa lezyonlarına yaklaşımda uygulanabilecek bir cerrahi yaklaşımdır. Klivus ve petroz kemiğin drillenmesi, petroz internal karotis arterin mobilizasyonu bu cerrahi yaklaşımdaki ana unsurlardandır. Petroz internal karotis arterin minimal cerrahi risk ile ortaya konması orta fossa ve petroz apeksin kompleks anatomik yapılarının ayrıntılı olarak bilinmesini gerektirmektedir.

Anahtar Kelimeler: Anatomi, infratemporal fossa, klivus, petroz karotis arter, trigeminal sinir

INTRODUCTION

It can be difficult to gain adequate surgical access to lesions anterior to the ventral brainstem involving the upper petroclival region, lesions of the posterior cavernous sinus, and those in the infratemporal fossa. Direct anterior and inferolateral approaches have been used to reach these areas. Fisch described and later Fisch et al. popularized the use of infratemporal approaches to access lesions of the lateral skull base (2,3,4). The subtemporal preauricular infratemporal approach is a modification one of Fisch's classic approaches (10,11,12). Though it offers excellent access to the regions of interest mentioned above, the exposure is complex, requiring extensive bone removal and mobilization of the petrous internal carotid artery. Our aim in this investigation was to define of the anatomy of the floor of the middle fossa in order to safely identify, preserve and mobilize the petrous internal carotid artery.

MATERIALS AND METHODS

This study was performed in the Harvey Ammerman Neurosurgical Laboratory at The George Washington University School of Medicine, Department of Neurosurgery. Ten adult cadaver specimens with intracranial arteries and veins injected with colored silicon were used. After the vessels were injected, the subtemporal preauricular infratemporal approach was performed. A Carl Zeiss Universal S2 operating microscope was used during dissection of the anatomic structures on the floor of the middle fossa, and for drilling of the petrous bone and clivus. Drilling was done with a Midas Rex (Texas, USA) high-speed air drill. Marathon 8-inch/ 200-mm Electronic Digital Calipers were used for all measurements.

Each dissection was done with the cadaver head in three-quarter prone position in three-point fixation to approximate the true intraoperative position. A question-mark skin incision was made. The incision was started just anterior to the tragus, with the lower edge of the cut extending low enough to expose the posterior zygomatic root (Figure 1). The skin was reflected to the point just anterior to the frontozygomatic suture and zygomatic arch. The temporalis fascia was incised along the arch to expose the deep temporal fat. The skin and temporalis fascia were then completely mobilized to expose the zygomatic arch and the frontozygomatic process. This step preserves the frontotemporal branch of the facial nerve. After the skin and subcutaneous tissue were mobilized in the temporal region, the parotido-masseteric fascia was dissected and separated from the parotid gland. Dissecting the parotido-masseteric fascia free minimizes traction on the facial nerve when the mandibular condyle is reflected inferiorly. Once this was done, the zygomatic arch and frontozygomatic process were completely denuded of periosteum and exposed.

The temporalis fascia and muscle were incised and reflected antero-inferiorly to the region of the infratemporal crest. Further mobilization of the muscle cannot occur without detaching the zygoma. The first burr hole was made either over the pterion or at the keyhole. The second burr hole was placed just superior and posterior to the bony external auditory meatus. After the craniotomy was performed the operating microscope was brought into the field. The temporal dura was gently separated from the most lateral part of the floor of the middle fossa. The arcuate eminence was identified, and this marked the posterior limit of the dissection. Dural separation was continued anteriorly to the foramen spinosum, where the middle meningeal artery was visualized entering the cranial cavity.

The next step was a zygomatic condylar osteotomy (Figure 2). Anteriorly, a V-shaped cut was made at the level of the frontozygomatic and zygomatico-maxillary sutures. Before making the posterior cut, the capsule of the temporo-mandibular

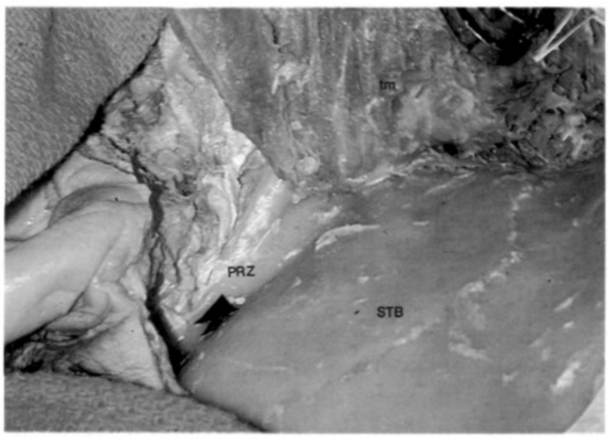

Figure 1: The position of the posterior root of the zygoma is identified. This extracranial landmark must be visualized to perform a condylar osteotomy. (PRZ = posterior root of the zygoma; STB = squamosal portion of the temporal bone; tm = temporalis muscle)

Figure 2: The hash lines show the V-shaped condylar osteotomy posteriorly and the zygomatic osteotomy anteriorly. The V-shaped cut is made lateral and posterior to the foramen spinosum and the middle meningeal artery. The arrow points to the condylar fossa. (tm = temporalis muscle; mma = middle meningeal artery)

joint was exposed, cut sharply and the meniscus of the joint was separated from the condylar fossa. The posterior cut was then made and the zygomatic arch was removed (Figure 3). In performing this osteotomy, care must be taken not to enter the middle ear cavity (Figure 4). Once the arch was removed, the floor of the middle fossa was dissected to expose the mandibular (V3) and maxillary divisions (V2) of the trigeminal nerve. Dissection between the arcuate eminence and the middle meningeal artery exposed the lesser superficial petrosal nerve extending towards the foramen ovale. Once this nerve was cut, medial separation of the dura continued. The middle

Figure 3: A large frontotemporal craniotomy and a condylar orbitozygomatic osteotomy have been performed. The arrow indicates the condylar fossa. (ftd = frontotemporal dura; o = orbit; tm = temporalis muscle)

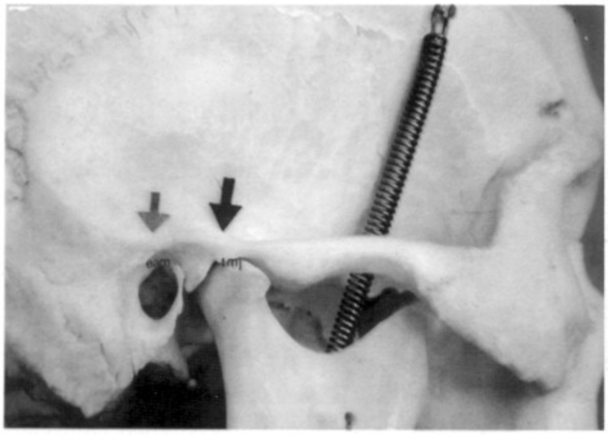

Figure 4: A dry skull specimen showing the proximity of the temporomandibular joint to the external auditory meatus. When performing the condylar osteotomy, care must be taken to avoid entering the external auditory canal. (eam = external auditory meatus; tmj = temporomandibular joint)

meningeal artery was also transected to permit further medial dissection and to expose the greater superficial petrosal nerve emerging from the facial hiatus. A venous plexus, an extension of the cavernous sinus, was observed surrounding the branches of the fifth cranial nerve. There was also a venous plexus in the region of Meckel's cave.

The greater superficial petrosal nerve was sectioned and further medial elevation of the dura exposed part of the horizontal segment of the petrous internal carotid artery. The horizontal part of the petrous internal carotid artery was covered with either thin bone, fibrous layer or no bone. The portion of the middle fossa lateral to the greater superficial petrosal nerve, V3, and V2 was drilled to expose the lateral part of the root of the pterygoid process. Drilling the bone of the middle fossa between V2 and V3 may expose the sphenoid sinus (Figures 5 and 6). The internal carotid artery was usually surrounded by a venous plexus. While drilling the bone laterally, the tensor tympani muscle and eustachian tube were identified and transected. Once these structures were cut, drilling was continued to expose the superior, lateral, and inferior walls of the horizontal part of the petrous internal carotid artery. This vessel was then completely free to be retracted anteriorly. While drilling posteriorly, care should be taken not to encounter the cochlea. The petrous pyramid was drilled completely to expose the dura of the posterior fossa, which was bounded by the superior petrosal sinus above and the inferior petrosal sinus below. The dura was opened in the region of Meckel's cave (Figure 7).

The following distance measurements were made: foramen spinosum to foramen ovale; foramen ovale to foramen rotundum; foramen rotundum to superior orbital fissure; foramen spinosum to lateral wall of the internal carotid artery; foramen ovale to lateral wall of the internal carotid artery; geniculate ganglion to intersection between the lateral margin of V3 and the greater superficial petrosal nerve; and geniculate ganglion to foramen spinosum. Diameter measurements were recorded for the foramina spinosum, ovale, rotundum, and lacerum, as well as the superior orbital fissure. Also noted were the location of the greater superficial petrosal nerve in relation to the internal carotid artery, and the presence or absence of bone between the greater superficial petrosal nerve and the internal carotid artery.

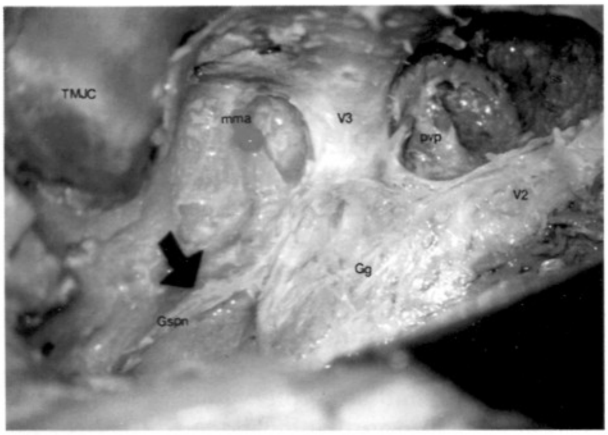

Figure 5: After the temporal dura is elevated from the floor of the middle fossa, the roofs of the foramina spinosum, ovale, and rotundum are removed. Once this is done, the pterygoid venous plexus is exposed. The arrow identifies the greater superficial petrosal nerve. (TMJC = temporomandibular joint capsule; Gspn = greater superficial petrosal nerve; mma = middle meningeal artery; Gg = gasserian ganglion; pvp = pterygoid venous plexus; ss = sphenoid sinus; V3 = mandibular nerve; V2 = maxillary nerve)

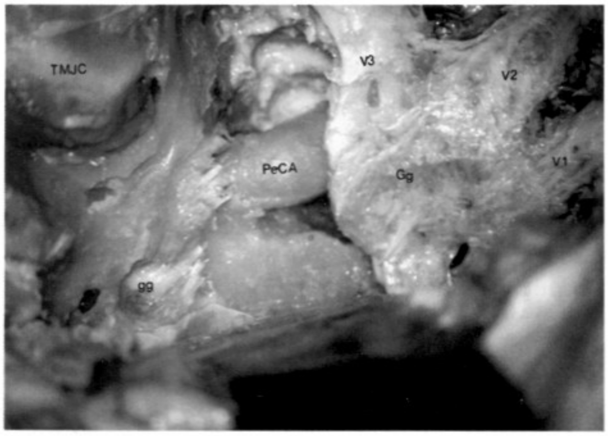

Figure 6: The bone covering the horizontal petrous carotid artery has been removed. (gg = geniculate ganglion; TMJC = temporomandibular joint capsule; Gg = gasserian ganglion; V3 = mandibular nerve; V2 = maxillary nerve; V1 = ophthalmic nerve, PeCA = petrous carotid artery)

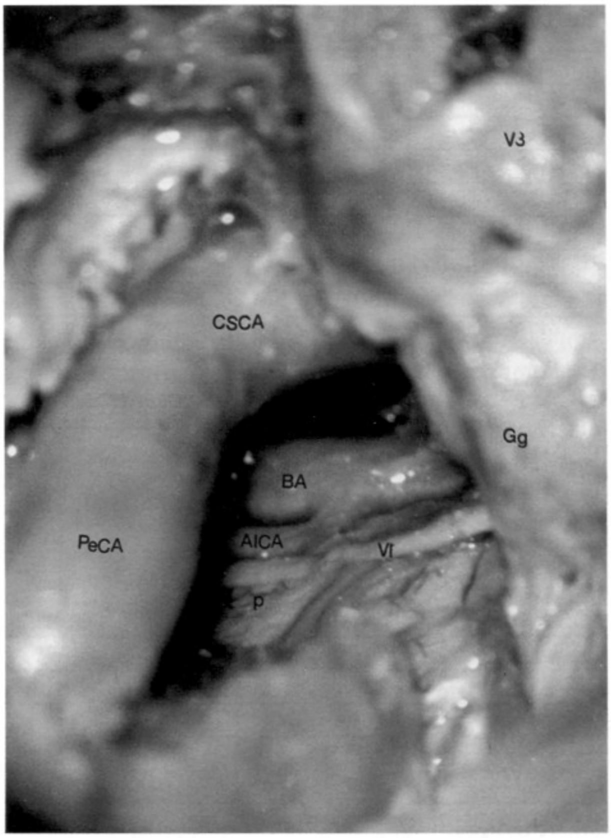

Figure 7: After the petrous carotid artery has been mobilized and the petrous apex has been drilled, the dura in the posterior fossa is opened. V3 has been transected near the foramen ovale. (PeCA = petrous carotid artery; CSCA = cavernous segment of the carotid artery; Gg = gasserian ganglion; V3 = mandibular nerve; BA = basilar artery; AICA = anterior inferior cerebellar artery; VI = abducens nerve; p = pons)

RESULTS:

The diameters of the middle fossa exit foramina, the distances between these openings, and the relationship of the lateral wall of the petrous internal carotid artery to these foramina are recorded in Tables 1 and 2. The relationship of the geniculate ganglion to the foramen spinosum, and to the intersection between the greater superficial petrosal nerve and V3 are also shown in Table 1. We found no significant differences between the left- and right-side measurements in any of the specimens studied.

The greater superficial petrosal nerve was located over the posterior third of the carotid on 12 sides (60%), the medial third in 4 sides (20%), and the anterior third in 4 sides (20%). Nine sides (45%) had no bone between the carotid and the greater superficial petrosal nerve, 6 sides (30%) had thin bone, and 5 sides (25%) had thin bone with a fibrous layer.

Three large venous plexuses were encountered during this approach. The first was the pterygoid

Table 1:

DISTANCE	RANGE (mm)	AVERAGE (mm)
SOF-FR	2.20-5.43	3.66
FR-FO	8.14-10.64	9.09
FO-FS	1.17-7.47	3.11
FS-LICA	4.0-8.0	5.86
FO-LICA	6.0-8.0	7.0
V3/GSPN-gg	14.0-17.0	15.3
FS-gg	13.0-16.0	14.6

SOF: Superior orbital fissure, FR: Foramen rotundum, FS: Foramen spinosum
LICA: Lateral wall of horizontal petrous internal carotid artery, gg: Geniculate ganglion
GSPN: Greater superficial petrosal nerve, V3: Mandibular nerve.

Table 2:

DIAMETER	RANGE (mm)	AVERAGE (mm)
FS	1.17-3.05	2.48
FO	4.33-6.94	6.01
FR	2.46-3.49	3.11
SOF	17.8-22.1	20.02
FL	3.5-5.0	4.3

FS: Foramen spinosum, FO: Foramen ovale, FR: Foramen rotundum
SOF: Superior orbital fissure, FL: Foramen lacerum.

venous plexus, the second was between the fibrous layer and the horizontal segment of the petrous carotid artery, and the third was located in the petroclival region. The foramen of Vesalius was found on six sides, transmitting a large emissary vein from the cavernous sinus in each case.

DISCUSSION

Infratemporal fossa approaches were first described by Fisch to address lesions of the lateral skull base (2,3). The subtemporal preauricular infratemporal approach is a modification of Fisch's techniques, and has been used to access pathology in regions anterior to the ventral brainstem, the petrous apex, the infratemporal fossa, and the posterior cavernous sinus (5,10,11,12). Anterior approaches offer an excellent route for resecting midline lesions; however, when the pathology is more laterally placed, they do not enable the surgeon to identify the location of the petrous internal carotid artery early in the exposure. The disadvantages of more inferior or inferolateral approaches are that cranial nerves obstruct visualization, and, again, early identification of the petrous internal carotid artery is problematic (13). The subtemporal preauricular infratemporal approach offers the advantage of early identification and mobilization of the petrous internal carotid artery. However, thorough knowledge of the anatomy of the region is essential to realize the maximum benefit of the exposure provided.

In our dissection using this approach, we consistently encountered three large venous plexuses. The first is the pterygoid venous plexus encountered during drilling bone to uncover the foramen ovale and foramen rotundum and drilling of the greater wing of the sphenoid bone. The second plexus envelopes the petrous internal carotid artery. A fibrous layer overlies this heavy venous network. The integrity of this fibrous layer should be maintained in order to avoid excessive blood loss. The third plexus lies in the petroclival region, and is associated with the superior and inferior petrosal sinuses. In addition, the foramen of Vesalius, which is found medial to the foramen ovale and was identified in six (30%) of our dissected sides, contains a large emissary vein draining the cavernous sinus (6). Care must be taken to avoid these venous structures in order to minimize blood loss during an operative procedure.

The measurements we made during the dissection reveal that the smallest opening is the foramen spinosum (approximately 2.5 mm), and the largest is the foramen ovale (approximately 6.0 mm). As documented previously, we observed that the carotid artery passed through the petrous bone medial to the foramen spinosum and foramen ovale (7). The largest distance between foramina was that between the foramen rotundum and foramen ovale (approximately 9.1 mm). This is of surgical significance because drilling the bone between these two openings allows a transcranial extradural entry into the sphenoid sinus.

The greater superficial petrosal nerve was always found overlying and running parallel to the petrous internal carotid artery; however, its exact location over the artery was variable. In 12 dissections (60%), the nerve was found lying above the posterior third of the internal carotid artery, in 4 dissections (20%) it was situated over the anterior third, and in the remaining 4 (20%) it was lying above the medial third. Dew et al. found that the greater superficial petrosal nerve passed directly above and parallel to the internal carotid artery in 21% of their specimens. In 7%, the nerve was either medial to lying over the medial aspect of the artery, and in 64% it ran medial to lateral over the artery and continued its anterior route lateral to the artery (1). Naquib et al. also found a variable but parallel course of the greater superficial petrosal nerve in relation to the carotid artery (8). They found that the intersection of V3 with the greater superficial petrosal nerve was always found to overlying the petrous internal carotid artery.

In our cadavers, we found that the petrous internal carotid artery was not always covered by bone. In 9 (45%) of the dissections, there was no bone separating the greater superficial petrosal nerve from the petrous carotid artery. Similarly, Paullus et al. found that approximately half of their 50 carotid arteries were not covered by bone (9). Injury to the petrous carotid artery can occur if the greater superficial petrosal nerve is not dissected carefully.

For the subtemporal preauricular infratemporal approach, the geniculate ganglion and the cochlear apparatus mark the lateralmost limit of the dissection. In our dissections, on average, the distance between geniculate ganglion and the intersection of the greater superficial nerve with V3 was 15.3 mm, and the distance from the geniculate ganglion to the foramen spinosum was 14.6 mm.

The subtemporal preauricular infratemporal approach offers the aforementioned benefits of early identification and mobilization of the petrous internal carotid artery, direct unimpeded access to the region of the petrous apex, minimal brain retraction, preservation of the hearing apparatus, preservation of the facial nerve, avoidance of traversing nasal sinuses, and ease of reconstruction. However, one disadvantage is the need to disarticulate the mandibular condyle for condylar resection, which may lead to trismus or malocclusion if realignment is not done properly. Another drawback is the need to mobilize the petrous internal carotid artery in order to gain access to the region of the petrous apex. Failure to mobilize the carotid artery greatly minimizes the exposure gained with this approach. A further issue is that the eustachian tube must be sacrificed in this approach, and this may lead to delayed middle ear pathology.

The advantages of the subtemporal preauricular infratemporal approach for anterolateral skull base lesions far outweigh the disadvantages; however, this technique requires extensive exposure, and demands patience and diligence. A thorough knowledge of the surrounding anatomy is crucial to the successful performance of this approach.

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